MODIS Snow and Ice Project
Quarterly Report
January – March 1998
Submitted by: D.K. Hall/974

Algorithm Code Deliveries:

MOD_PR29A1 Version 2.0, the MODIS L3 daily sea ice algorithm was delivered to the CMO of SDST on 13 January.

MOD_PR10 Version 2.1, the MODIS L2 snow algorithm, was delivered to the CMO of SDST on 20 March.

Algorithm Refinements:

The MODIS snow and sea ice algorithms were analyzed and revised, integrating new decision processes and metadata in the algorithms and data products.

Improved visualization and analysis tools were used in development and analysis of the MODIS snow and sea ice algorithms, including tools for investigation of MODIS input data products to those algorithms. Also developed were new visualization and analysis tools for the data products and input data products.

Miscellaneous

A MODIS Snow Products User's Guide was drafted by G. Riggs/RDC.

A field program in North Dakota and Minnesota was supported.

Presentations

G. Riggs made a presentation of the quality assessment, automated and interactive, strategies for the the MODIS snow and sea ice data products at the MODLAND-SDST meeting 11-13 February.

D. Hall/974 gave a seminar on the MODIS snow and ice project to a group of MIT students on 28 January.

D. Hall gave talks on snow and sea ice validation plans for MODIS for the EOS PM1 project, at the EOS PM1 Validation Meeting on 1 – 2 April.

A. Klein gave a seminar on the MODIS snow and ice project to a group of City University of New York students on 16 April.

Abstracts and Publications

1. G. Riggs and D.K. Hall, “Detection of Sea Ice with the Moderate Resolution Imaging Spectroradiometer Airborne Simulator,” AGU – 26-29 May 1998, Boston, MA.

Abstract

Sea ice detection and classification by reflective and temperature characteristics using a grouped threshold criteria technique from Moderate Resolution Imaging Spectroradiometer (MODIS) Airborne Simulator (MAS) data is presented. The MAS is a 50 narrow-band channel (0.55 um- 14.2 um) instrument which was flown aboard the NASA ER-2 aircraft over the Bering Sea near St. Lawrence Island, Alaska, USA, on 8 April 1995.

Sea ice classification was done using reflective and ice surface temperature (IST) characteristics. Reflectance was calculated using flight calibration data. Ice surface temperature was estimated using a split-window technique. The University of Wisconsin cloud mask algorithm was used to distinguish between sea ice and cloud. Extent and type of sea ice were classified separately by reflectance characteristics and IST. Sea ice was classified as new ice or snow-covered ice by reflectance characteristics and as new, young, or first and multiyear ice by IST. The sea ice classifications by reflectance, and IST were then melded to create a joint sea ice-classification map to compare and contrast the agreement and disagreement between the two separate classifications. Sea ice types classified agreed with sea ice types and locations reported by other investigators for this location.

The sea ice classification technique and the resulting sea ice classification map are the prototypes of the MODIS sea ice data product developed for the Earth Observation System Data and Information System (EOSDIS).

2. D.K. Hall, J.L. Foster, V.V. Salomonson, A.G. Klein and J.Y.L. Chien, “Estimation of the Errors in Snow-Cover Mapping in North America using Satellite Data,” - Eastern Snow Conference, 4-5 June 1998 – Jackson, NH.

3. A. Tait, “High Frequency Passive Microwave Radiometry over a Snow-Covered Surface in Alaska - Eastern Snow Conference, 4-5 June 1998 – Jackson, NH.

Abstract

Millimeter-wave Imaging Radiometer (MIR) data (ranging in frequency from 89 to 325 GHz) collected from NASA ER-2 flights over Alaska in April 1995, are used to identify clouds, vegetation type, and snow cover. The procedure used is as follows : 1.) Determine whether a purely MIR-based cloud detection scheme is possible over a snow-covered surface; 2.) Analyze the influence of changing vegetation type on the brightness temperatures; and 3.) Compare completely snow-covered scenes with partially snow-covered and snow-free regions for cloudy and clear-sky periods to determine whether varying snow conditions affect the MIR data. Results show that the determination of cloudy pixels over a snow-covered surface is not possible using a simple brightness temperature threshold technique. Furthermore, it is concluded that while no statistical discrimination between specific vegetation classes can be made, statistical significance is obtained when the vegetation is grouped into two classes only, for example vegetated and barren. It is also shown that the state of the snow cover (complete coverage; melting; or patchy) has a distinct effect on these results.

4. A. G. Klein, D.K. Hall and K. Seidel, "Algorithm intercomparison for accuracy assessment of the MODIS snow-mapping algorithm - Eastern Snow Conference, 4-5 June 1998 – Jackson, NH.

Abstract

MODIS, the Moderate Resolution Imaging Spectroradiometer, is scheduled for launch in June 1998 aboard the first Earth Observing System (EOS) platform. Global, daily snow-cover maps will be produced at a spatial resolution of 500 m from MODIS data using a fully automated and computationally frugal algorithm. Several modifications to the original snow-mapping algorithm have been made to improve mapping accuracy in forests.

The accuracy of snow maps derived from the original and enhanced MODIS snow-mapping algorithms was assessed through comparison with three other snow-mapping products. Two of these products, one developed at the University of California–Santa Barbara (UCSB) for the Sierra Nevada, and another developed at the Eldgenössische Technische Hochschule Zürich (ETHZ) for the Upper Rhein-Felsberg basin in Switzerland, are area-specific. The third is an operational snow-cover product produced for portions of the United States and Canada by the National Operational Hydrologic Remote Sensing Center (NOHRSC). In all three comparisons, the products from both MODIS algorithms compare well with products produced from the other algorithms. The enhanced MODIS algorithm consistently mapped a higher proportion of pixels identified than the original, suggesting it offers improved snow detection.

Unlike the MODIS binary (snow/no snow) algorithms, the UCSB algorithm provides quantitative estimates of the snow-covered area (SCA) which is the fraction of each pixel covered by snow. Comparison of the UCSB and MODIS algorithms for a May 10, 1991 Landsat Thematic Mapper (TM) image indicates that for both the original and enhanced MODIS algorithms, pixels with approximately 50% or higher SCA are mapped as snow. The MODIS algorithms correctly identified 93% or greater of the pixels with SCA estimates of 50% or more. However, the enhanced MODIS algorithm classified more pixels with <50% SCA as snow than did the original MODIS algorithm (24% compared to 6%) thus more closely matching the results of the SCA algorithm.

The accuracies of the MODIS algorithms compared to the algorithm developed at ETHZ for May 25 and July 12, 1994 Landsat TM scenes were mixed. The ETHZ algorithm identifies both snow and transitional (50% snow) pixels. For the May 25 scene, both MODIS algorithms correctly identified the majority of snow pixels as snow (70% and 85% for the original and enhanced algorithms, respectively). Lower percentages of the transitional snow areas (32% and 48%, respectively) were correctly mapped. However, accuracies for the July 12 scene were lower - 45% and 54% for the original and enhanced algorithms, respectively. Less than 20% of the transitional areas were correctly mapped.

Snow cover products produced using the MODIS algorithm with Landsat TM images were acquired over portions of New Hampshire and New York in January and February 1997. These were compared to the operationally-produced NORHSC snow maps for the same time period. The enhanced MODIS algorithm mapped a significantly higher proportion of each TM scene as snow than did the original MODIS algorithm (19% and 36% for New Hampshire and New York, respectively). Visually, the NORHSC snow-cover maps are in much closer agreement with the enhanced MODIS algorithm while the original algorithm is more affected by land-cover variations.

5. A.G. Klein, D.K. Hall and G.A. Riggs, "Global Snow Cover Monitoring Using MODIS," - 27th Symposium on Remote Sensing of the Environment, 8-12 June 1998.

Abstract

Snow is an important and highly variable land-surface cover which plays an important role in controlling the energy fluxes between the land and atmosphere. From a human standpoint, snow represents an important water resource and has a profound impact on human health and safety in many areas of the

world. Despite its importance, global maps of snow-cover extent with sufficiently high spatial resolution for many environmental applications are not routinely produced for many areas of the world.

In June 1998, the Moderate Resolution Imaging Spectroradiometer (MODIS) is scheduled for launch aboard NASA's Earth Observing System (EOS) AM-1 spacecraft. MODIS is designed for environmental monitoring of the land, oceans and atmosphere. The 36 spectral channels in the reflective and thermal infrared wavelengths, 250 to 1 km spatial resolution and cloud masking capabilities of MODIS will enable the production of better maps of global snow cover than is possible with currently polar orbiting satellites such as the Advanced Very High Resolution Radiometer (AVHRR). MODIS will image the high latitudes, which contain the vast majority of the Earth's seasonally snow-covered areas, daily while snow cover in the lower latitudes will be monitored every other day.

The MODIS snow-mapping algorithm has been developed using Landsat Thematic Mapper (TM) and MODIS Airborne Simulator (MAS) images. The algorithm utilizes the seven visible to short-wave infrared MODIS bands suitable for land-surface remote sensing to produce global daily snow-cover maps with 500 meter spatial resolution for individual MODIS swaths. Snow-cover maps produced from the swaths are then spatially and temporally composited to produce higher-level snow-cover products, ranging from geolocated daily and eight-day composites at the original resolution to 1/4 by 1/4 degree products suitable for climate modeling studies.

Efforts are underway to assess the accuracy of the current MODIS snow-mapping algorithm as a function of land-cover type as well as to compare the MODIS snow-cover products produced from TM and MAS images to snow-cover maps produced using other data and different algorithms, including those produced operationally for the United States and Canada by the US National Operational Hydrologic Remote Sensing Center (NOHRSC). After the launch of MODIS, considerable efforts will be made to further refine and improve the MODIS snow-mapping algorithm to enable the production of accurate maps of global snow cover for use in a wide variety of environmental applications.

6. J.-G. Gunnar and D.K. Hall, “Satellite-derived snow coverage related to hydropower production in Norway – present and future,”– 27th Symposium on Remote Sensing of the Environment, 8-12 June 1998.

7. D.K. Hall, J.L. Foster, V.V. Salomonson, A.G. Klein and J.Y.L. Chien, “Error Analysis for Global Snow-Cover Mapping in the Earth Observation System Era,” IGARSS’98, 6-10 July 1998, Seattle, WA.

Abstract

Following the launch of the Earth Observing System (EOS) satellite platform, daily, global snow-cover mapping will be performed automatically at a spatial resolution of 500 m using Moderate Resolution Imaging Spectroradiometer (MODIS) data. In order to estimate the accuracy of the MODIS snow maps, the Northern Hemisphere was divided into 7 land-cover classes and water, and expected errors in mapping snow were calculated for each of the 7 classes using the average monthly snowline position. The errors are found primarily in land covers composed of forests. Maximum monthly snow-mapping errors are expected to range from 5 – 9% for North America, and from 5 – 10% for Eurasia. The largest errors are expected when snow coverage in the Boreal Forest is greatest. The maximum aggregated snow-mapping error for the Northern Hemisphere is expected to be about 7.5%. Error estimates will be refined after the first full year that MODIS data are available.

8. A. Tait, High frequency passive microwave radiometry over a snow-covered surface, IGARSS’98, 6-10 July 1998, Seattle, WA.

Papers submitted for publication:

1. George A. Riggs, Dorothy K. Hall, and Steven A. Ackerman, “Sea Ice Detection with the Moderate Resolution Imaging Spectroradiometer Airborne Simulator (MAS),” Remote Sensing of Environment.

Abstract

An algorithm for mapping sea ice extent and classifying sea ice by reflective and temperature haracteristics with Moderate Resolution Imaging Spectroradiometer Airborne Simulator (MAS) data is presented. Results are discussed for a MAS scene of sea ice in the Bering Sea near St. Lawrence Island, Alaska, USA, acquired 8 April 1995. MAS data were converted to reflectance or brightness temperature prior to analysis in the algorithm. A split-window technique was used to estimate ice surface temperature. The University of Wisconsin cloud masking algorithm was employed to mask clouds from the sea ice algorithm. Interpretation and use of data in the cloud mask to achive accurate masking of clouds is discussed. Sea ice extent was mapped and sea ice types were classified separately based on reflective characteristics and ice surface temperature using a grouped threshold methodology. Sea ice classification in the region studied was consistent with sea ice types and distributions reported in other studies of the region. Two sea ice maps of extent and ice type were created based on separate groups of reflective and temperature tests for sea ice characteristics. These different sea ice maps were melded to compare and contrast the occurrence and typing of sea ice by reflective or temperature characteristics. Clouds were masked in the scene, and the extent and type of sea ice was mapped. The algorithm presented is the prototype for the MODIS sea ice algorithm.

2. D. K. Hall, J.L. Foster, D.L. Verbyla, A.G. Klein and C.S. Benson, “Land and Forest-Cover Classification using Aircraft and Satellite Data in Snow-Covered Areas in Central Alaska,” Remote Sensing of Environment.

Abstract

Field and aircraft measurements were acquired in April 1995 in central Alaska in order to map snow cover using Moderate Resolution Imaging Spectroradiometer (MODIS) Airborne Simulator (MAS) data. A vegetation-density map derived from integrated reflectances (R_i), from MAS data, is compared with an independently-produced vegetation type and density map derived from thematic mapper (TM) and ancillary data. The maps agreed to within 13%, thus corroborating the effectiveness of using the reflectance technique for mapping vegetation density. Snow cover was mapped on a 13 April 1995 MAS image, using the original MODIS prototype algorithm and an enhanced MODIS prototype algorithm. Field measurements revealed that the area was continuously snow covered. With the original algorithm, snow was mapped in 96.41% of the pixels having <50% vegetation-cover density according to the R_i map, while in the areas having vegetation-cover densities ≥50%, snow was mapped in only 71.23% of the pixels. When the enhanced MODIS snow-mapping algorithm was employed, 99.33% of the pixels having <50% vegetation-cover density were mapped, and 97.73% of the pixels with ≥50% vegetation-cover density were mapped as snow covered. These results show that the enhanced algorithm represents a significant improvement over the original MODIS prototype algorithm especially in the mapping of snow in dense vegetation, and the enhanced algorithm will thus be adopted as the MODIS at-launch snow-cover algorithm. Using this simple method for estimating vegetation density from pixel reflectance, it will be possible to validate the MODIS snow-cover algorithm in a range of land-cover types following the launch of MODIS, a 36-channel spectroradiometer, in 1998.

3. J.-G. Winther and D.K. Hall, “Satellite-derived snow coverage related to hydropower production in Norway – present and future,” submitted to International Journal of Remote Sensing.

The following draft has been prepared, and is undergoing internal review before submittal to a journal:

A. Tait, D. Hall, J. Foster and A. Chang, "Detection of snow and vegetation cover using millimeter-wave imaging radiometer (MIR) data."

Abstract

Millimeter-wave Imaging Radiometer (MIR) data (ranging in frequency from 89 to 325 GHz) collected from NASA ER-2 flights over the Great Lakes region, New England, and Ontario in February 1997, are used to identify vegetation and snow cover. A Normalized Difference Vegetation Index (NDVI), derived from Advanced Very High Resolution Radiometer (AVHRR) data, is used to determine vegetation type. Snow and cloud cover are obtained using the Moderate Resolution Imaging Spectroradiometer (MODIS) snow mapping algorithm and cloud masking algorithm performed on MODIS Airborne Simulator (MAS) data. Results show that for cloud-free scenes the MIR atmospheric window channels (89, 150, and 220 GHz) are well related to the snow and vegetation cover, which are also strongly related to each other. Furthermore, there is some indication that the variability within the MIR data may be related to patchy snow and percent forest-covered area. Under cloudy conditions the MODIS snow mapping algorithm is unable to detect snow on the surface. However, it is shown that surface features are clearly discernible using millimeter-wave radiation data at 89 GHz. A snow cover model is developed using these data and surface air temperature data obtained from the NOAA Climate Diagnostics Center (CDC) reanalysis for the ER-2 flight on 9 February 1997. The model is tested on a different flight and is shown to be effective for clear and cloudy conditions over this area. It is suggested, though, that this model may not be suitable for all regions and for all times of the year.

Problems

G. Riggs received notification (3 April 1998) from SDST that of the three format options (full, compact, one layer) for the L2G product, only the compact format will be generated in production from this time forward. This is a change in production policy. The Level 3 MODIS snow and sea ice algorithms were designed to read only the full format of L2G. The impact of the change is that the data ingest structure of the snow and sea ice algorithms (MOD_PR10A and MOD_PR29A) will have to be changed, as will the software tools used for visualization and analysis of L2G data.